Shock persistence in space: a challenge for cliometrics

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Shock Persistence in Space: A Challenge for Cliometrics

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Abstract: *»Persistenzeigenschaften eines Schocks im Raum. Eine Herausforderung für die Kliometrie«.* The 'memory' feature of shock is important both from the time and spatial perspective. A cliometric challenge can be to study the 'memory structure of shock and its behavior in a spatial setting', a widely neglected dimension in the literature.

The dictum of traditional economic theory says that a shock in an economic system exerts only short-run or transitory effect, completely disappearing in the long-run. The economy can be in a temporary disequilibrium, and after a shorter-span of spurts and fluctuations, it carries the tendency to converge to the level of long-run equilibrium. Permanent fluctuations were not considered impossibility, but the probability of permanent fluctuations, according to conventional thinking, was rather very little since demand and not the supply disturbances were thought to govern economic dynamics. However, modern growth theory has established rules closer to reality that shocks may persist and that they may not converge in the long run, or even if they converge they will leave long-lasting impact on economic performance. Therefore study of shocks has gained rapid momentum and occupied centre stage in modern economic literature, with one important exception – there is no clear cut underlying mechanism that characterizes properties of shock persistence in a *spatial* setting. Extant literature has provided evidence that study of spatial movement of shocks is exceedingly complex and throws lot of complications as monitoring their very movement over time and across space is a methodological nightmare.

Despite the existence of inherent core of complex characteristics, a very natural characteristic of 'shock' is that it governs spatial and temporal dynamics of a system and consequently affects its evolution with attendant long-run

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(growth) implications. In recent years, particularly in the last decade, a lot of efforts have been put on the characterization of 'accumulation' of shocks in an economic system purely from *temporal* point of view. For instance, we 'shock' an inflation series (in other words, impart 'one unit innovation' to it) and study the nature of persistence or continuation of shocks over time. Alternatively, researchers have investigated how shocks travel over *time* and if the magnitude of the shock remains the same or deteriorate over the time span. However, there is virtually little literature that explains the dynamics of shocks in a *spatial* setting. This void in the literature is not something that was not thought over by researchers over decades, but in most likelihood, it appears to us that the lack of seriousness was due to the underlying methodological complexities.

Indeed, the non-stationary nature of economic variables purely from temporal point of view began to have serious momentum only after Dickey and Fuller's (1979) seminal contribution to the unit root literature, and later due to the exhaustive applications by Nelson and Plosser (1981) that most of the macroeconomic aggregates exhibit unit root characteristics. That is, a shock imparted to a series carries the natural tendency to persist for long. Therefore, relevant counter-cyclical policies need to be designed to deter their progression. Spatial economics as a separate branch in economics and statistics got established in the past two decades or so. And at a time while, statistical theories were undergoing massive shift to a new paradigm of 'non-stationary' statistics, it took a hefty two decades to think about 'non-stationary' features in space. Despite all rigorousness in time dimension, nature of shock persistence is not clearly defined in a spatial context – only occasionally studied by some very inquisitive economists (for instance Fingleton, 1999, and Mur and Trivez, 2003).

Given this backdrop, it is reasonable to give serious thought in developing methods that describe spatial dynamics in the presence of stochastic shocks. The extant spatial econometric literature has thus far been unkind in dealing with the issue of non-stationarity in a spatial setting, thus conveniently assuming stationary nature of space in which economic variables act and interact. The central objective of this project is to first provide exploratory mechanism that treats '*Why non-stationary shocks should draw an attention in a spatial context?*' '*How does one describe stochastic shock behavior in a spatial setting?*' And '*How does one formulate a spatial non-stationary process?*' The project intends to address these questions comprehensively by outlining what economic processes give rise to spatial non-stationary processes. And then we devise method to describe non-stationary spatial process with different memory properties of shocks. On the whole, this project aims to provide a new theoretical formulation for spatial models where the interaction in the space by different agents may not be assumed stationary in the restrictive sense. We posit that a shock may be stationary yet it can persist for some time before ultimately converging to the steady state values. This 'memory' feature of shock is important both from the time and spatial perspective. In case of the former, theoretical contributions abound, for the latter there is a clear dearth of literature. A cliometric challenge can be to study the '*memory structure of shock and its behavior in a spatial setting*', a widely neglected dimension since the last two decades. To address the issue, we outline new methodological tool in terms of 'spatial long memory data generating process' and with the help of some important economic problem like common cyclical shocks or demographic dynamics, we put our model into empirical scrutiny.

The research problem

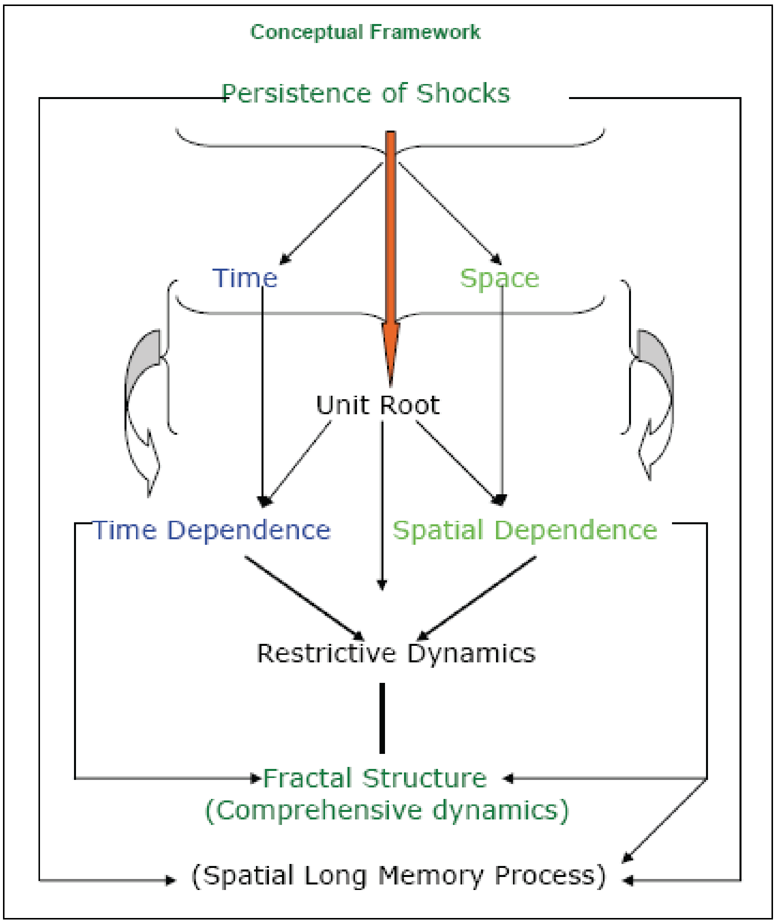
The study of shock persistence – be it in a spatial or temporal setting – is important in its own right as 'there is no single entity in the universe – smaller or bigger – which escapes the effect of shocks'. The greater is the 'persistence' of shocks in a system, the bigger is the possibility that the 'system' is volatile, more chaotic and hence more unpredictable. Accurate 'predictability' is a great virtue as we live for the future and therefore, we must know in what way the shock is going to shape up the future and influence the long-run evolution of the system. To our surprise, it appears to us that over the past decades analysis of shock persistence has been limited mostly to the time domain, neglecting a natural dimension – the space.

Shocks do not travel in 'emptiness'. It travels in 'space'! Therefore, the spatial dimension of shock's movement is as important as time dimension. Though every point in space has a natural reference to time, till date, there is no literature that studies effects of shocks in spatial setting. Anselin and numerous other authors have tried to study the time series version of econometric properties of spatial processes, for instance the spatial version of autoregressive and moving average processes. While it is relatively easy to study time series characteristics of shocks, a direct translation of the method in spatial setting is beset with multiple problems. The foremost lacunae arise in the context of '*accumulation mechanism of shocks*'. In fact, it is the consideration of this mechanism we are interested in a spatial setting. A small example would help understanding of the problem.

In a time series context, a variable's evolution can be described by its historical growth. For instance, higher population growth in a developing country can be expected to result from high past population growth rates. So the current value of the variable, if depends on the past and remote past values, we say there is a certain 'memory' structure. In effect, it can be said that if there is a shock in the series in the past, due to the property of history dependence, the shocks carry to the present and would possibly be carried in the future. The higher is the persistence of shocks, greater is the memory of the series to remember past shocks; consequently such series are treated as highly volatile. In statistical terminology we call it as a unit root process (in a restrictive framework) or using the modern development a 'fractional process'. Fractional processes are more flexible as they provide a transition route to a variable to *gradually* become non-stationary. Indeed, non-stationarity is a big problem for economists as it implies the presence of a stochastic non-mean convergent shock in the system, which unless treated, might cause a system failure. In time dimension, shocks accumulate over time, and little by little, it would proliferate in the long run and cause chaos in the system.

This cogent expression of stochastic shock behavior in time does not so far find an equivalent expression in a spatial context, which is a major objective of the project. Like temporal dimension, persistence of shocks in space and its accumulation mechanism is rather difficult. There could be two assumptions. We may either assume 'time being fixed' and show how shock accumulate from one point in space to the other or we can keep space constant and study how shocks accumulate over time in the 'fixed space'. A natural question may arise: *Does space evolve over time?* A straightforward answer is that space does not evolve but spatial phenomenon like 'economic or demographic distance' – defined by different metric of measurement – might vary over time. In spatial economic set up, 'space' generally refers to 'economic space' which has some intrinsic properties (See Conley, 1999), which can evolve over time. Even when we refer to geographical distance, say different countries or regions, shocks move from region to region or country to country and take time to affect spatial destinations. Therefore, while setting a spatial model for growth, it is essential to take into account the time movement of shocks. This is precisely the leading idea of the project. We recognize that whether space is defined in terms of geographic or economic term, shocks evolution can be monitored using the properties of both spatial and time characteristics. Fingleton (1999) was the first to introduce the concept of unit root in a spatial autoregressive process and Mur and Trivez (2003) provided simulation examples to explain the accumulation mechanism of shocks as defined by Fingleton (1999). In these studies, time has not been treated explicitly, accumulation of shocks has been defined across spatial units, which the authors reiterate that it does not resemble time series version of accumulation as the weight of shocks at different spatial points do not decline systematically. Fingleton (1999) outlined a mechanism where he describes how a 'unit root kind of behavior can occur' in spatial context. It appears to us that the unit root concept as used by Fingleton is just for the statistical wisdom that a value of 1 for an autoregressive parameter causes non-standard distribution. In case of spatial model, it gives rise to circular weight matrix. The solution of the problem was devised by the author by appropriately transforming the spatial weight matrix.

This statistical rigorousness needs re-examination as 'time' does not seem to enter the discussion in terms of explicit formulation. Spatial model following Fingleton does not carry time series characteristics – a point which is well taken care of in this project. We allow time to play crucial role in the spatial movement of shocks and study their long-run and short-run behavior across different spatial units. Therefore we study individual as well as aggregate spatial dynamics incorporating time dimension. The state of the art literature exhibiting the treatment of shocks in time and so far in the spatial dimension is provided in the conceptual framework below.



Our idea is to model spatial dependence with long-memory characteristics of shocks, i.e., the fractional process. *We combine Space and Time characteristics to design a long-memory spatial data generating process.*

The Methodological framework

The methodological framework of the project will draw rigorously on both spatial economics and statistics literature and time series econometric methods. The theoretical mechanism edifices on the mechanism of shock analysis considered from macroscopic point of view. Micro-foundations of our method rests on the specific way we treat each and every spatial unit with distinct characteristics embedded in a spatial system. In time series, a variable's evolution is judged over a time horizon, especially how the series has evolved over time with the property of 'history dependence'. From spatial economic theory literature, we study various convergence properties of spatial units in a large spatial system and particularly how one treats shocks in this case. Our approach is then to integrate the two strands of literature to study dynamics of shocks in a spatial system over time. Since our objective is to provide a spatial long memory data generating process, the following steps describe how we would design a data generating process and implement it with some practical examples.

Step 1: Design a spatial process first with spatial weight matrix and spatial autoregressive term

Step 2: Add time dimension to the weight matrix and a fractional operator to the spatial autoregressive process. Then we study the 'shock accumulation' mechanism in this set up.

Step 3: The data generating process is now a spatial long memory process due to the fact that 'the spatial model' is governed by memory characteristics of shocks. Over time the memory recedes and over longer horizon the system may stabilize. Thus we study the convergence properties of shocks 'over time' and 'across spatial units'. Consistency of the results is proved for large spatial units.

Step 4: We design a spatial autoregressive fractionally integrated moving average, i.e., Spatial ARFIMA model and by simulation show that when there is perfect memory or very high persistence, the spatial system is unreliable and there can arise chaotic behavior.

We suggest applying our methodological framework to two economic situations, viz., demographic system with common demographic shocks for a large number of countries, and a spatial growth model where some countries share common technological progress. There can be numerous applications of the method, though we concentrate on two methods for the sake of convenience and wider economic applicability and appeal. World economy is in a state of tantrum; while some countries are going to face larger stock of retired cohorts, others might face very high growth working age population. In effect, there can be downturn of economic growth for some and upturn for others. In this context, our idea would be to check for the dynamics of demographic change over the past years in a spatial setting and correctly design economic policy for optimum distribution of and transfer of resources. The same thing can be studied in case of the second example, as to what specific dynamics govern some countries to experience higher technological growth and some lower and importantly if there is a stochastic technological shock in one country how it is going to affect others over time. Basically taking into account the long memory spatial framework we would like to study the convergence pattern of shocks in space and depending on the rate of convergence design policies to counter the effects of shocks.

Innovative aspect and scientific importance of the research

Study of spatial dynamics is an arduous task. Till date researchers have flocked to the point of expanding theories and explaining spatial characteristics of some of the most important economic problems. Geographic models, for instance, analysis of diffusion or innovation with geographical characteristics are in close proximity to spatial dynamic model. Yet, to our knowledge there is very little research in the literature about how a stochastic shock affects spatial dynamics, what is the nature of stochastic shock in the space, and especially how does it accumulate over time? These are a few important questions, which remain unanswered due to methodological complexity or hardness of modeling the core of the spatial process with time dimension. Though there are a few notable exceptions, like Fingleton (1999), and Mur and Trivez (2003) who tried to use the time series version of unit root methodology in a spatial context, there is no comprehensive study that describes the exact mechanism of shock persistence in space. Moreover, the modeling of a spatial unit root (as in Fingleton, 1999) is much too restrictive an assumption to outline exact mechanism of shock persistence. The proposed study aims to fill the void in the literature.

The innovative aspect of our project lies in designing a mechanism that describes movement of spatial shocks and the exact way they affect the economic system. Specifically, we design a data generating process (DGP) for a spatial non-stationary process. Formulation of a DGP for a spatial process that exhibits shocks with various rates of decay is never an easy task. Using fractal method in time series, we provide a long-memory DGP for a spatial process that evolves over time. Our contribution is as follows. Contrary to standard literature, where time is not explicitly modeled or at times implicitly referred for model specification, we explicitly model time in a spatial process. We posit that a spatial characteristic evolves over time and therefore a shock that originates in one point in space takes its natural time to travel to other points in the space. Consequently, there can be a spatial chaotic behavior. The purpose of the project is to provide an explicit formulation of spatial dynamics with time series characteristics. The methodological innovation of this project is expected to solve some of the big puzzles in spatial economics literature, viz., how to monitor shocks in space. Most importantly, it is no more be needed to impose the stringent assumption that spatial shocks are stationary in nature. Stationary assumption is too restrictive as it outright downplays the various length and extent of shocks in space. Mapping out their different rates of decay or convergence in the long-run and across spatial units, our methodology will help in providing an important formulation of shock-mechanism in space.

Knowledge of the exact mechanism by which shock accumulates in space, equips us with appropriate policy options to counter the effects of short, long, or medium-run shocks in space. Our mechanism would help in defining different convergence pattern of shocks over time and across space. Moreover, spatial long-memory process is more flexible, easy to handle and more informative than spatial unit root process. The latter formulated first by Fingleton (1999) does not exactly define the shock accumulation mechanism as in time dimension of unit root. An attractive feature of our method is to provide a time variant of shock accumulation mechanism in space. So far, spatial economists relied heavily on spatial dynamics which assumed stationary movement of shocks – a feature less close to real life situations. Our methodological innovation is expected to resolve some of the key problems in spatial economics in this regard.

Besides the methodological innovation of the project, the relevance of the project cogently extends to important branches of economics and demography. Spatial characteristics are inherent in many sociological, economic and demographic problems. For instance, it is not surprising to see that some countries or regions experience faster aging or even some regions in a country have faster technological progress than others. But how does one capture this spatial phenomenon and study over time? How does shock accumulate in space and bring in chaotic spatial dynamics resulting in policy failures or providing an unstable vision of future? Moreover, in the topological space of firms, it may be of interest to know how the network evolves over time and what are the spatial characteristics of network's evolution defined over time? These are a few intriguing questions which can possibly be answered by modeling spatial shocks in a long memory framework to which the proposed project tries to give a modest attempt. The impeccable existence of space is infrequently incorporated in describing economic problems. Given their presence as assured as the existence of life is, dynamics of a particular system is studied, be it economic, demographic or sociological. Realizing that shocks are difficult to model due to their complex web of interactions with economic system, over the decades we have been treating the spatial dynamics of shocks as inherently stable or stationary. Assuming the stationary core of the space, economic, demographic or different sociological problems are studied. In light of these, the proposed project is of prior scientific importance as we provide a simple framework for studying spatial shocks, their stability and convergence properties and the way they interact with different agents in the space. Apart from many areas of economics and sociology, our project can make useful contribution to the following two important problems the world is facing.

First, the veritable importance of demography in economic growth has reached a new height recently after research proved that much of the economic growth fluctuations are caused by demographic instability. Researchers (like Boserup, 1965) have also established that technological innovation is caused by 'demographic pressure'. Therefore, characterization of demographic dynamics is central to characterizing economic fluctuations, apart from the standard emphasis of technological fluctuations. Interestingly, demographic fluctuations that occur in one country move faster to other regions of the world. Typically this is spatial movement of shocks which needs to be characterized and studied in depth to understand its influence on economic growth fluctuations. A typical example as briefly mentioned in the preceding paragraph, that some countries experience faster ageing, or lower fertility rate or even baby booms than others. To capture this dynamics in 'space' (i.e., across difference countries and different regions) and study the time profile of effects on these countries as well as others, a dynamic spatial process is needed. Particularly if we are interested how this 'spatial phenomenon' is going to affect long-run growth of these countries and intergenerational transfer of resources, then a spatial dynamic model is needed to capture their impact. Our methodological framework of long-memory spatial process has the ability to provide a broad formulation of spatial movement of shocks. A spatial unit that carries a strong memory of demographic shocks and carries it to other spatial units, there is more likelihood of a spatial chaos, where the system might fail to stabilize.

Today's world economy is more integrated than before. National economic boundaries remain, yet the nations are urged to fast integrate their economies with new world economic order. It is like 'keeping up your identity while you are in the midst of a group', where we carry individual as well as group idiosyncrasies. It is not difficult to imagine that amidst such degree of 'integratedness', instability of economic or demographic order in one country can significantly weigh the balance in other points in the space. In fact, some countries react to shocks in a different way than others. Based on this 'spatially different characteristics' of shocks, many points in the space (or many countries in the world as in our case) can be classified according to 'common spatial shocks'. Putting this into perspective, using our framework, the spatial characteristics of shocks, the nature of convergence and the time profile to be taken to convergence can be easily calculated. In fact, world economic bodies are finding it hard to model common spatial shocks in a realistic framework where shocks are non-stationary and have long term impact on the economy. To this end, our design of spatial long memory process is useful.

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